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Forecasting Research

Forecasting Research Division
Technical Report No. 88

An operational trial to validate the use of Balanced Mass Increments derived from Assimilation Wind Increments

by

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March 1994

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1. Introduction

Andrews and Bell (1993), described an additional balance step (WINDBAL), in which balancing surface pressure and potential temperature increments are derived from the non-divergent part of the wind increments. The preliminary experiments discussed in that report showed some deteriorations in some of the scores which resulted in the scheme being unacceptable for operational use. A small revision to the algorithm was designed to overcome this problem (section 2); and a second parallel run was done to validate the revised version (section 3).

2. Changes to the WINDBAL Algorithm

Several off-line tests (not described here) were conducted to determine the best option for resolving the problems identified in the first trial. We identified the problem as being due to the upper level temperature increments derived from surface winds.

In this latest trial, we still calculate the surface pressure and temperature increments as described in Andrews and Bell (1993) or alternatively in UMDP 30 version 4 at section 7.3, equations 7.17b and 7.20 (Bell et. al., 1993). These balancing increments were used exactly as in the preliminary trial for the upper level wind increments. For the surface wind increments, only the 'WINDBAL' surface pressure increments were used. These had been validated successfully during an operational trial of the scatterometer winds (Bell, 1994) and have been used operationally since August 1993.

The upper level derived temperature increments from analysed surface wind increments were reformulated as hydrostatically balanced potential temperature increments from the WINDBAL derived surface pressure increments. This utilises the same code and algorithm as for the balancing temperatures derived from the analysed surface pressure increments. Details can be found in UMDP 30 version 4 at section 7.1, equations 7.11 (Bell et. al., 1993).

3. Results

A global trial of 'WINDBAL' was conducted from 16th December 1993 through to the 4th January 1994. It followed the usual format established by parallel trial runs, a global data assimilation cycle plus a main 12GMT assimilation. In this trial, the forecast run from the 12GMT main assimilation was reduced to 3 days because of scheduling constraints. The verification also followed the usual format, namely an observation processing database (OPD) was generated from the data assimilation cycle giving departures from analysis and background for all observation types; and a 24 hourly verification against SYNOPs and radiosondes of the 12GMT forecast averaged over the standard verification areas (North Atlantic sector- area 2, and three latitude bands - areas 200, 300 and 400 for 90°-30°N, 30°N-30°S and 30°-90°S respectively)

3.1 OPD comparison

A clean comparison of the data assimilation statistics could not be achieved because of unexplained discrepancies in the observation counts. There were rather more observations in the trial database than there were operationally. The difference in data volumes was of order 1-3% and probably resulted from a duplicate run in the trial or a missed run operationally. This difference probably would not have much impact on the conclusions.

3.1.1 Surface data

As in the first trial, the rms surface pressure observation minus background (o-b) difference for the trial were within 0.01 hPa of the operational values. An improvement in the rms for global ship data was offset by a slight deterioration for global land synop data.

The rms vector wind (o-b) difference for surface ships showed the trial to have a closer fit in all latitude bands but especially in the southern hemisphere (by 1.5% or 0.08 knots). The northern hemisphere improvement was 0.5%

Taking these two results together, we can say that at the surface the impact was marginally positive.

3.1.2 Single level upper winds

The tables 1 and 2 below give global results in terms rms vector wind difference for aireps and satobs for selected wind speed bands and a contingency table showing the frequency distributions as a function of the same wind speed categories. In these and subsequent tables the better score is highlighted.

speed	oper airep	trial airep	oper high-level satob	trial high-level satob	oper low-level satob	trial low-level satob
0-5	3.34	**3.22**	2.74	2.74	2.11	**2.10**
5-40	**5.88**	5.93	5.85	**5.79**	3.52	**3.43**
40-80	7.24	7.24	6.94	**6.85**	2.79	**2.72**
80-120	**8.16**	8.21	9.10	**9.00**	x	x
120-160	8.39	**8.38**	**10.60**	10.68	x	x
>160	**7.52**	7.54	**11.65**	11.79	x	x
all	**7.22**	7.25	6.67	**6.59**	3.38	**3.29**

Table 1 rms vector wind error for airep and satob differences from trial and operational backgrounds (units: knots, area: global)

Speed	Obs frequency	Trial frequency	Oper frequency
0-5	1.2%	1.0%	1.0%
5-40	25.7%	**27.8%**	28.3%
40-80	37.4%	36.5%	**36.6%**
80-120	21.9%	**21.9%**	21.2%
120-160	10.2%	**9.5%**	9.4%
>160	3.5%	3.4%	3.4%

Table 2 Frequency of occurrence of observation and model backgrounds in each of speed categories. (units knots, area global)

We see from table 1, the trial is better when compared against satobs both at high and low levels, but marginally worse when compared against aireps. Table 2 indicates that the trial backgrounds have larger frequency of occurrence in the higher wind speed categories which is a correct signal and is quite likely to account for the higher rms difference.

A breakdown by latitude band shows that for aircraft data, (in the pressure range 100-400 hPa) we see a 2.3% reduction in rms vector wind difference (rmsvwe o-b) in the trial southern hemisphere results. Outside the southern hemisphere the signal is reversed (1.0% worse in the tropics and 0.4% worse in the northern hemisphere).

The results for cloud track winds show improvements both at low and high levels in all three latitude bands. Above 400 hPa, the improvement for the three latitude bands is 1.0%, 1.0% and 2.4% for northern, tropical and southern latitude bands respectively. Below 400 hPa, the improvements are 1.1%, 3.1% and 1.6% for the same three areas.

It is interesting to speculate on the reason for the rather better signal given by the satob validation. One possible reason might be that the satobs are wind only observations and the derived temperature increments are more beneficial in those areas.

Taking these results as a whole, it seems that again the trial is also giving a modest improvement at upper levels.

3.1.3 Radiosondes

For radiosondes, the tables below show temperature and vector wind differences for the trial and operational runs for a selection of standard levels averaged over three latitude bands.

At T+6, the comparison of fit to backgrounds for temperatures, (table 4), shows the trial beating or equalling control at all levels in the northern hemisphere and all but 700 hPa in the other areas. For winds, (table 5), we see a clear impact; the northern hemisphere and tropics are better at all levels, whilst the southern hemisphere is worse at 700 hPa and above, which is in contradiction to the results for aircraft reports. Typical difference in scores are

around the 1% mark. These results support those from the single level data and show that the trial is giving a modest improvement at upper levels.

Observation-analysis differences are also available from the OPD. These show a closer fit at analysis time in the trial for both winds and temperatures at all levels. The figures are not illustrated as these details are also available from the forecast verification package which is discussed in the next section.

	850 hPa	700 hPa	500 hPa	250 hPa	100 hPa
NH-TRIAL	1.82	**1.45**	**1.33**	**1.61**	1.71
NH- OPER	1.82	1.46	1.34	1.63	1.71
TR-TRIAL	**1.60**	1.61	1.36	**1.45**	**2.19**
TR-OPER	1.62	**1.58**	1.36	1.46	2.21
SH-TRIAL	**1.90**	1.60	1.43	1.88	**1.60**
SH-OPER	1.94	**1.55**	1.43	1.88	1.61

Table 3 Radiosonde rms temperature differences from trial and operational backgrounds for each of three latitude bands

	850 hPa	700 hPa	500 hPa	250 hPa	100 hPa
NH -TRIAL	**9.34**	**9.01**	**10.31**	**12.48**	**10.45**
NH-OPER	9.43	9.09	10.42	12.64	10.56
TR-TRIAL	**8.60**	**9.27**	**10.24**	**14.32**	**14.83**
TR-OPER	8.68	9.28	10.34	14.35	14.86
SH-TRIAL	**12.93**	12.54	14.57	17.60	12.12
SH-OPER	12.99	**12.51**	**14.48**	**17.53**	**12.04**

Table 4 Radiosonde rms wind differences from trial and operational backgrounds for each of three latitude bands

3.2 Forecast verification

3.2.1 Against observations

It is clear from tables 3 and 4 that the differences between trial and control are rather modest. For clarity, the forecast verification scores are presented as a percentage change in rms error (defined as 100%*[oper. score - trial score]/oper. score, therefore negative represents a poorer trial performance). The results are presented for each verification area at 850 hPa, 500 hPa and 250 hPa for height, temperature and wind plus surface pressure at daily forecast periods out to T+72 hours.

	T+0	T+24	T+48	T+72
850 hPa height	0.5	0.3	-0.6	-0.7
500 hPa height	-0.3	0.1	0.6	1.0
250 hPa height	0.6	0.8	1.0	1.4
850 hPa temp	0.1	0.2	0.3	0.6
500 hPa temp	0.7	-0.3	0.9	1.5
250 hPa temp	1.6	0.7	0.8	0.0
850 hPa wind	0.2	0.7	0.3	0.1
500 hPa wind	0.7	0.9	0.2	0.2
250 hPa wind	0.9	0.5	1.6	0.7
pmsl	-1.0	0.4	-0.7	-1.0

Table 5 % change in rms score for extra-tropical northern hemisphere (see text for details)

The poor northern hemisphere forecast scores reported from the earlier trial have now been turned round in this latest trial. The table 5 scores are nearly all positive (trial better). The modest improvement noted in the early stages of the forecast is held onto through the 3 day forecast. There is a tendency for the improvement to be more marked at higher levels which might be expected given the nature of the change. The WINDBAL derived surface pressure increments from surface winds being already incorporated within the control run.

	T+0	T+24	T+48	T+72
850 hPa height	1.6	0.8	-0.4	0.4
500 hPa height	-0.6	-0.9	-0.8	-0.3
250 hPa height	-1.2	0.1	0.2	0.8
850 hPa temp	-0.7	1.5	1.7	0.8
500 hPa temp	0.7	0.2	1.4	1.0
250 hPa temp	-0.1	-0.2	-0.5	-1.1
850 hPa wind	0.3	0.4	0.0	-0.5
500 hPa wind	0.5	0.4	0.1	0.7
250 hPa wind	0.8	0.4	0.9	-0.1
pmsl	-0.4	-0.8	0.0	-1.0

Table 6 % change in rms score for tropics (see text for details)

	T+0	T+24	T+48	T+72
850 hPa height	-2.0	0.2	2.9	2.2
500 hPa height	-0.9	-0.3	1.5	0.5
250 hPa height	2.1	0.5	1.7	2.3
850 hPa temp	-0.6	1.1	1.1	0.4
500 hPa temp	-0.4	-1.9	2.5	2.5
250 hPa temp	3.8	0.0	0.2	-0.1
850 hPa wind	2.7	1.7	3.6	4.0
500 hPa wind	3.9	1.3	1.9	0.9
250 hPa wind	-0.6	-0.7	-0.7	-0.6
pmsl	-0.2	1.3	1.6	1.9

Table 7 % change in rms score for extra-tropical southern hemisphere (see text for details)

Tables 6 and 7 give the same results for the tropics and southern hemisphere. In the tropics, the results are more mixed, but perhaps favour the trial slightly especially at T+24 and T+48 (more positive scores than negative scores). In the southern hemisphere, the trend is also for a general improvement in scores of the trial run compared with the operational run. This is more noticeable at the later forecast periods; at T+48, improvements are typically 2%.

Taking one key field, the northern hemisphere 250 hPa winds, we examined the daily time-series of scores. The number of individual trial runs better/worse than operational was 14/3, 13/3, 13/3, and 7/7 for each of the forecast periods from T+0 through to T+72 respectively. This indicates that the modest improvement was a consistent signal.

3.2.1 Against analyses

The same marginal signal was noted in the verification of forecasts against analyses. Less weight can be put on these results as each system has its forecast verified against its own (and therefore different) analysis. The results are presented (table 8) simply in terms of the trial being better or worse than the operational system. (✓= trial better, x= trial worse and .= results identical to 2 decimal places.)

In table 8, we see only marginally more ✓ than x. We see that heights are generally improved in the extra-tropics at all forecast periods and also in the tropics at T+24. The results for heights favour the control beyond T+24 in the tropics. We see that wind scores are improved for all areas and all forecast periods, except in the southern extra tropics at T+72. Offset against this improvement is an apparent deterioration in temperature scores, particularly in the tropics and southern hemisphere extra-tropics.

	T+24			T+48			T+72		
	NH	TR	SH	NH	TR	SH	NH	TR	SH
850 hPa height	.	.	.	x	x	✓	x	x	✓
700 hPa height	✓	.	✓	x	x	✓	.	.	✓
500 hPa height	x	.	✓	.	.	✓	✓	✓	✓
250 hPa height	x	x	x	✓	x	✓	✓	x	✓
100 hPa height	✓	x	✓	✓	x	✓	✓	x	✓
850 hPa temp	.	x	x	✓	x	x	✓	x	✓
700 hPa temp	x	x	x	x	x	x	x	.	x
500 hPa temp	x	x	x	.	x	x	.	x	x
250 hPa temp	x	x	x	x	x	x	x	x	x
100 hPa temp	.	.	.	✓	.	✓	✓	.	✓
850 hPa wind	✓	.	x	✓	x	✓	x	x	x
700 hPa wind	✓	✓	.	✓	✓	✓	✓	.	x
500 hPa wind	✓	✓	✓	✓	✓	✓	✓	✓	x
250 hPa wind	✓	x	✓	✓	x	✓	.	✓	✓
100 hPa wind	✓	✓	✓	✓	✓	✓	✓	.	✓
pmsl	.	x	x	x	x	✓	x	x	✓

Table 8 Indication of the trend in verification of forecast against analyses

3.3 Subjective assessment

The T+72 surface pressure charts and the T+24 250 hPa wind charts were compared. No particular signal was noted in what was a brief comparison (which is not presented here in any detail). Examination of difference charts yields significant areas of difference on every case which when the pairs of charts are compared prove to be the result of rather small displacements in systems which have large gradients associated with them. Figures 1 and 2 are illustrative of this. They show the T+72 forecast surface pressure differences and the T+24 forecast 250 hPa wind differences from one case (30 Dec) taken at random. 5 major low pressure systems were forecast stretching from Japan eastward to the UK. The trial was lower in two lows by 1 hPa and 2 hPa and the same for the other three lows. Clearly the larger differences of up to 7 hPa in Figure 1, resulted from small displacements n forecast position, usually by no more than 1 grid-point. The same small differences were noted when comparing the upper jets. Two large bulls-eyes in the difference chart were result of small displacements rather than major changes. No jet was different by more than 1 m/s. The 15 m/s difference over France was entirely due to the slightly different shape to the jet.

4. Conclusions

This trial has demonstrated that a small improvement in scores (of order 1%) is likely from the use of balanced mass increments derived from the analysed wind increments. The signal was quite small and no significant impact on subjective forecasts was noted. Andrews and Bell (1993) discussed the improved balance which resulted from the use of WINDBAL. This aspect has not been re-examined, but we presume that the result obtained then is still valid since the revision to the original scheme which was included in this retest is relatively minor.

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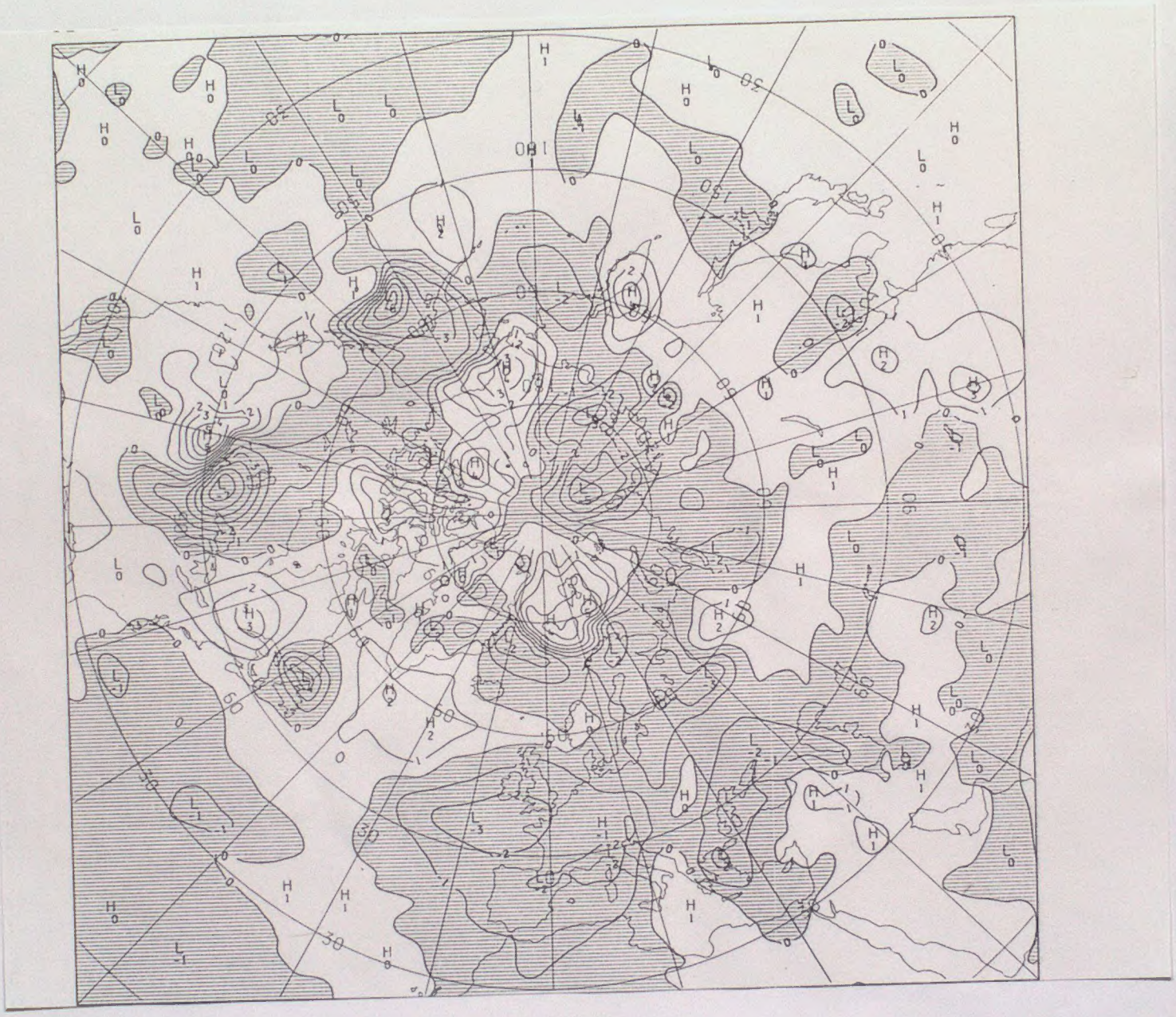

FIGURE 1 Example of forecast surface Pressure difference (Trial - Control) at T+72 from 12UTC 30/12/93 (contours: 1hPa, area Northern Hemisphere)F

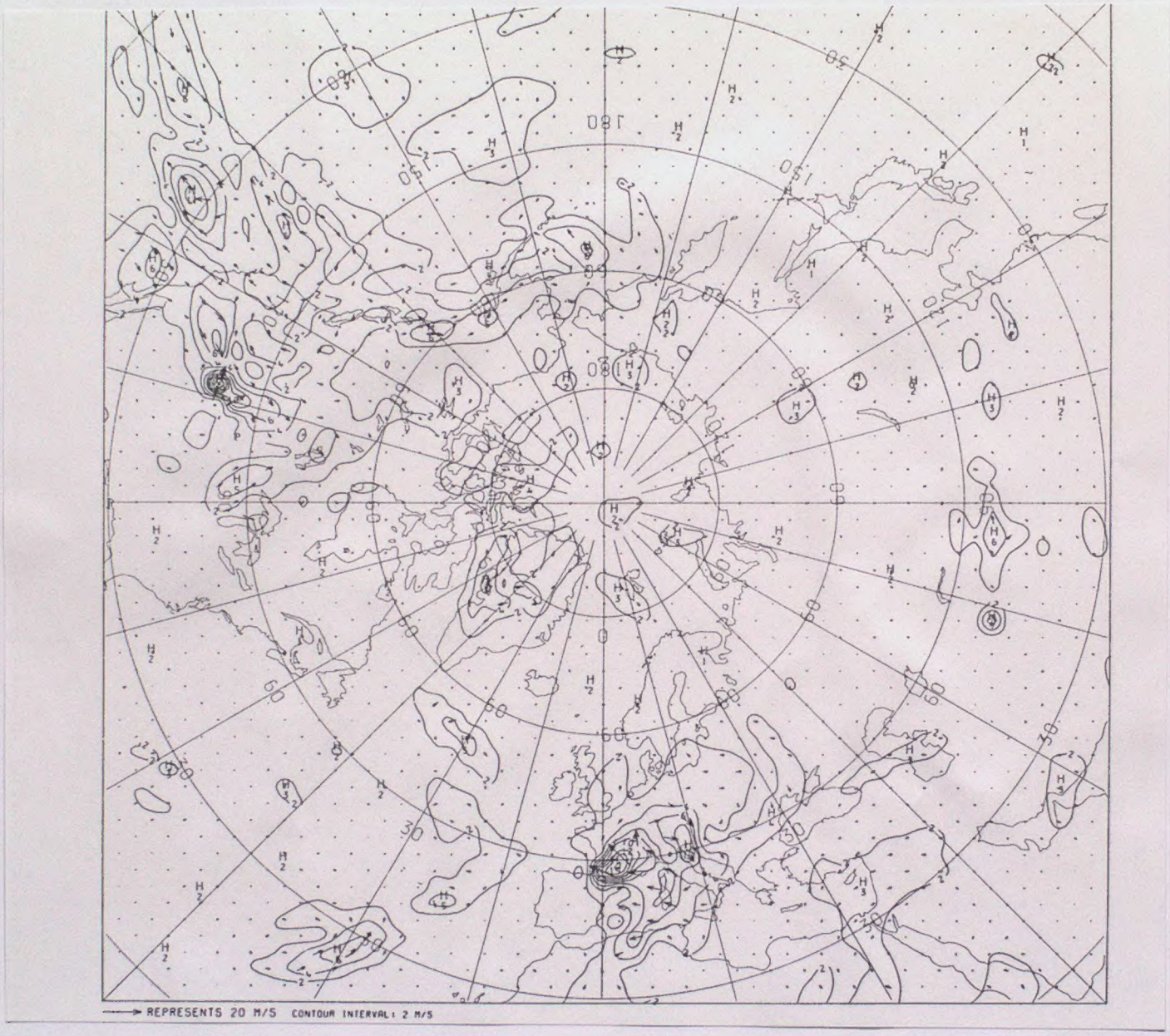

FIGURE 2 Example of forecast 250 hPa wind difference (Trial - Control) at T+24 from 12UTC 30/12/93 (speed difference contours: 2m/s; vector difference denoted by arrows; area Northern Hemisphere)